Towards a reference model for m-commerce over ad hoc wireless networks

Towards a Reference Model for M-Commerce over Ad Hoc Wireless Networks

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Abstract — Wireless trading outside established computer networks is an emerging class of mobile application for which there seems to be a growing demand. It enables mobile users to engage wirelessly in online trading regardless of time or location. However, better understanding of the complex issues at stake is needed before effective systems of this kind can be designed and built. Developing a reference model is one way to provide this understanding. M-commerce is defined and its elements, requirements and issues are discussed. The characteristics, functional components, application types, security requirements and issues of ad hoc m-commerce are then analyzed and distinguished.

Index Terms — e-commerce, mobile computing, spontaneous dealing, wireless trading.

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1 INTRODUCTION

Performing m-commerce transactions over ad hoc wireless networks or ad hoc m-commerce can be considered as wireless trading outside established computer networks. It enables users to engage in m-commerce transactions by using computing resources on nearby devices without the need for infrastructure support from a network service provider [1].

However, to make ad hoc m-commerce a reality, it is important to clearly understand ad hoc wireless networking as well as m-commerce concepts, requirements and challenges. Therefore, having a reference model should help to grasp the key issues involved in trading wirelessly among computing nodes in the absence of a network service provider. It will facilitate discussion on distinguishing aspects and issues of ad hoc m-commerce as well as be useful in identifying and facilitating Research and Development (R&D) for a wide range of ad hoc m-commerce applications. A reference model will:

1. Establish a taxonomy of terminologies, concepts and definitions required for describing ad hoc m-commerce.
2. Identify all the functional elements in ad hoc m-commerce systems and clarify dependencies among them.
3. Identify any issues that might restrain the development of ad hoc m-commerce that need to be addressed to realise it practically.

Hence, this paper proposes the elements of an ad hoc m-commerce reference model to serve as a basis for understanding the nature as well as the requirements for performing such trading. The rest of this paper is structured as follows. Section 2 discusses the nature of m-commerce, its functional components and also requirements. Section 3 discusses several essential m-commerce issues in detail. Section 4 describes ad hoc m-commerce and discusses its specific issues and possible applications. Section 5 concludes the paper.

2 M-COMMERCE

2.1 M-Commerce Definition

The term m-commerce has been defined in a variety of ways in different literatures [2],[3],[4],[5]. Some of these definitions seem to restrict m-commerce to business transactions that are conducted solely over a mobile telecommunication network and involve the transfer of monetary values. However, m-commerce transactions do not necessarily involve the transfer of money and can be conducted over other means of wireless communication. Furthermore, all commercial transaction steps need not be carried out electronically. While some transactions are initiated and completed electronically, some transactions may be initiated electronically but completed off-line.

Therefore, in this paper, m-commerce is defined as a set of activities relating to the

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exchange of information, services and goods for either money or other information, services and goods, which is conducted fully or partly online over wireless technology using mobile devices. In a fully online transaction, all transaction processes, which include the advertising, negotiating, ordering, payment and delivery processes, are conducted electronically. In a partly online transaction, the transaction may be initiated electronically but not completed electronically. Steps like the advertising, negotiating and ordering processes may be done online but other steps like payment and delivery processes may be done off-line.

M-commerce has several unique characteristics. Based upon different literatures [6],[7],[8] m-commerce's distinguishing characteristics can be summarized as follows:

1. Location and Motion Independence
   The portability of mobile devices, the pervasiveness of mobile network access and widespread m-commerce service availability makes m-commerce transactions possible irrespective of where the user is or whether the user is moving.
2. Localizability
   Technologies like Global Positioning System (GPS) enable users and mobile network operators to locate each other and to make access to commerce services specific to their location.
3. Personalisation
   Mobile devices are usually not shared among users. This enables users to customise these devices to their individual commerce service requirements.

2.2 M-Commerce Functional Components

M-commerce systems involves various disciplines and technologies [9]. In order to have a clear understanding of m-commerce systems, it is essential to identify their components as well as to recognize their functions and dependencies with one another. We follow [9] in dividing m-commerce systems into six components.

1. Mobile Commerce Applications
   There are a wide variety of existing and potential m-commerce applications. These applications can be classified into several classes as listed in table 1.
2. Mobile Stations or Devices
   Mobile devices with sufficient power in terms of memory, display and communications functionalities enable consumers to engage in m-commerce transactions regardless of time or location.
3. Mobile Middleware
   Mobile middleware can be defined as an enabling layer of software that joins together different mobile applications, networks and technologies via a common set of interfaces [10]. It enables m-commerce applications to function with greater reliability as well as to provide better response times.
4. Wireless Networks
   In addition to mobile devices and middleware, networking support from wireless networks plays an essential role in realizing m-commerce applications. Wireless networking technology available to support m-commerce includes operator-driven networks like GPRS and UMTS, wireless LAN via Wi-Fi (Infrastructure and Mobile Ad Hoc Wireless Network) and wireless PAN via Bluetooth.
5. Wired Networks
   Although this component is an option, most computers or servers that are used to execute transaction processes and store all the transaction information usually reside on wired networks.
6. Host Computers
   Host computers are used to process and store m-commerce transaction related information such as Web servers and database servers.

TABLE 1
CLASSES OF M-COMMERCE APPLICATIONS

Class of Applications	Examples
Information	News and Weather Maps and travel related information Logistical information Emerging service information
Entertainment	Sports, Games and Gambling e-Books, e-magazines Movies, images and music Streaming media
Financial	Banking Mobile Auctions Booking and Reservation Online shopping and stock trading
Marketing and Advertising	Mobile coupons and promotions

2.3 Main Entities in M-Commerce System

Generally, there are four main entities in m-commerce systems [11].

1. Customer
   The person who is mainly mobile and makes use of the m-commerce system for the purpose of obtaining and paying for contents, products or services offered by merchants or content/service providers.

2. Merchant or Content/Service Provider
   The entity that provides the contents, products and services to customers either directly or through a mobile network operator.
3. Mobile Network Operator
   The entity that provides the network connectivity that links customers, merchants and financial institutions.
4. Financial Institution
   The entity that provides the payment mechanism such as EFTPOS or ATM service.

2.4 Entities Relationships in the M-Commerce Value Chain

Entity relationships in an m-commerce value chain can vary depending on the types of transactions. For example, a relatively simple transaction such as buying a soft drink from a vending machine would only involve a customer, mobile network operator and its vending machine that supplies soft drinks [11]. In this scenario, the customer has relationships with both the mobile network operator and the vending machine. The mobile network operator charges the customer for using its service to purchase the soft drink by adding the cost of the soft drink to the customer's mobile phone bill.

A more complex m-commerce transaction might involve a financial institution. In this scenario, the customer has a relationship with the mobile network operator, the financial institution and also the merchant [11]. The mobile network operator enables the transaction to take place by providing mobile services to the customer. To purchase products, the customer needs a relationship with the financial institution that handles the transaction payments. The customer will also need a relationship with the merchant for the goods purchased.

Another scenario is a relationship between a customer and mobile network operator and also a relationship between a network operator and content provider [12]. The customer obtains the content or service from its provider through its mobile network operator and pays the operator who remunerates the content or service provider in turn.

2.5 M-Commerce Requirements

Although different m-commerce applications have different requirements, in general m-commerce applications have the following requirements:

1. Adequate quality of service in the wireless network to avoid delays that may affect the performance of m-commerce applications.
2. Reliability in the wireless network so that users can access m-commerce applications, even under varying degrees of network failure.
3. Ability to roam across multiple heterogeneous networks so that users can access m-commerce applications from anywhere.
4. End-to-end security supported so that trading parties can trust the other trading parties to provide their service at an acceptable level of risk.
5. Convenience and usability so that users can perform m-commerce transactions easily and unproblematically.

3 M-COMMERCE ISSUES

3.1 Mobile Devices

Mobile devices have limitations in terms of battery life, resources and display capabilities.

1. Battery life
   Mobile devices have limited battery lifetimes during which they can operate without recharging their energy resources. This limitation restricts mobile devices from performing much complex and energy intensive computations. Moreover, the use of a wireless medium for data transmission can make the battery life shorter as it consumes significant energy [3]. Therefore, mobile devices cannot be expected to be always available in a network like stationary computing devices. Users may cut their wireless connection to the network to reduce power consumption or the battery may suddenly become flat.
2. Limited resources
   Mobile devices have limited resources in terms of CPU capacity, storage capacity and processing space due to their small size and portability. These limitations restrict the amount of computation performed and also the amount of data stored on these devices.
3. Small screen and keypad
   The small screens and limited text input capabilities of mobile devices limit the size of information that can be displayed and make data entry more difficult. Also, they limit capabilities for use of high quality graphics [3].

3.2 Wireless Networks

Wireless networks have limited bandwidth. Although they may come to have higher bit rates, the transmission rates in many wireless networks such as in cellular or satellite networks are still low as compared to wired networks [3]. This is partly because wireless communications are rather more error prone and require much redundancy in the channel coding of the payload [3].

In addition to that,wireless networks are less reliable due to frequent network disconnections. Factors that cause network disconnections include lack of network coverage, cell interference, changes in the signal strength and limited battery lifetime of mobile devices. In some m-commerce applications such as online trading or entertainment, continued network connectivity is an important requirements as discontinued connections may affect the result of transactions.

Furthermore, channels in wireless networks may be asymmetric [13]. The bandwidth available for uploading data may be rather lower than the bandwidth available for downloading data.

Also, different networks have different network access charges. In some networks, access is charged per connection-time for example in cellular telephones, while in some others, it is charged per message or per session [3].

3.3 Security

There are at least three aspects of security that need to be considered: the security of mobile devices, the radio interface and payment systems.

1. Mobile devices
   Due to their small size and portability, mobile devices are prone to be stolen, lost or accidentally damaged. Since these devices are highly personalized and are often used to store confidential user information, it is important to protect not only the data that is transmitted through the network but also the data on the device itself. However, their limited computation capabilities and memory size make it difficult to use high level security schemes.
2. The radio interface
   Performing electronic transactions over wireless networks is inherently insecure as compared to wired networks [12]. A radio interface introduces additional security vulnerabilities. Its broadcast nature makes it easier for attackers to intercept and spoof on going traffic if no security mechanisms such as communication encryption are employed. There are three common types of attacks: disclosure attacks, integrity attacks and denial of service attacks [14]. Disclosure attacks are where the confidentiality of data transmitted over the network is compromised by its contents being revealed to other parties that are not involved in the communication by means such as eavesdropping, masquerading, traffic analysis and so on. Integrity attacks are where the contents of a message being transferred over the network is illegally altered or deleted or reused without permission. In a denial of service attack, access to the network is made impossible by flooding and overloading the network with messages. In addition to security attacks, frequent handoffs and disconnections due to path loss, fading and interference can degrade the service levels of security services. Also, the mobility of mobile devices introduces an additional difficulty in identifying and authenticating devices in the network.
3. Payment System
   M-commerce applications, especially those involving mobile payments require secure information exchange as well as safe electronic financial transactions. Without a secure payment system, neither customers nor merchants may be prepared to engage in monetary m-commerce transactions. For instance, both parties that are involved in a financial transaction would want to authenticate each other before committing to any payment. Also, they would want assurance on the confidentiality and integrity of the sent payment information as well as effective support for non-repudiation to prove that a transaction has happened.

3.4 Social, Ethical and Legal Issues

To avoid risks such as legal actions, brand infringement and so on, entities that are involved in m-commerce transactions must ensure that all m-commerce activities such as services, transactions, payments and so on, comply with government and industry regulations. Regulatory issues that need to be addressed include:

1. Data protection and data breaches

___Regulations related to the protection of subscriber data, identity theft and the reporting of data breaches.

2. Digital rights
___Digital content such as music, clip art, videos and so on are subject to intellectual property (IP) constraints such as copyright, trademarks and patents.
3. End-user privacy
___Regulations related to consumer protection and privacy laws to ensure consumer privacy is not violated.
4. Child protection
___Regulations related to offering, accessing and purchasing of adult related content, products and services. Age verification may be required before any adult related content, products or services are obtained.
5. Money laundering and gambling
___Regulations related to electronic money transfers, money trafficking issues and so on.

4 M-COMMERCE OVER AD HOC WIRELESS NETWORKS OR AD HOC M-COMMERCE

Unlike infrastructure-supported m-commerce, ad hoc m-commerce takes place between 2 or more mobile devices that are peers and in the vicinity of each other. To accomplish a transaction, these devices communicate and cooperate with each other by utilizing their local resources and also their neighbours', without relying on any support provided by a network service provider. Thus, ad hoc m-commerce can be said to have the following characteristics:

1. No network service provider
___Because ad hoc wireless networks lack a network service infrastructure and are self-organized, a network service provider cannot be relied upon to be present to provide other security or payment services whenever nodes engage in m-commerce transactions.
2. Limited communications scope
___IEEE 802.11 (Wi-Fi) and Bluetooth have limited communication ranges [15],[16]. Therefore, such networks are suitable for short range node to node communication. While nodes can bridge gaps by routing information over multiple hops via nodes in between themselves and so extend the range of such networks, those ad hoc connections via intermediaries may not be long lasting and may not be available much of the time.
3. Limited time online
___Due to limited battery lifetimes and the mobility of mobile devices as well as frequent network disconnections, there is a limited time during which these devices can be online, which restricts them from engaging in lengthy and complex transaction processes. This means that transactions need to be completed in a fairly short period and only comprise a few simple stages if they are to have a good chance of success. Therefore, realistic transactions must not involve long sessions or complex processes. Since mobile devices are peers and these devices themselves can become the service or information provider as well as the consumer, the limited time online restricts a trusted service or information provider from providing ubiquitous services such as payment processing, or information such as a good trading history to other devices in the network.
4. Spontaneous decisions in Ad Hoc Settings
___The self-organizing characteristic of an ad hoc wireless network allows users that are equipped with mobile devices to spontaneously engage in m-commerce transactions when the need arises while they are on the move. For example, passengers in two cars near each other in slow traffic can establish an ad hoc wireless network connection and exchange video clips while within range of each other.
5. Low cost
___An ad hoc wireless network provides a low cost wireless connection for users to engage in m-commerce transactions. No additional device is required to perform ad hoc m-commerce as mobile devices that form the network will utilize their local resources and also resources on other devices in their proximity area in order to accomplish the transactions. The cost of purchasing or renting additional devices such as special server(s) that are used to process the transaction as well as to store transaction information is eliminated. Also, buyers or traders save on network access charges.
6. Confidentiality
___Because no third party needs to be involved to realise network communication, the range of wireless communication is limited, and can be conducted on the move, ad hoc m-

commerce is suitable for confidential commercial exchanges where the trading parties do not wish their exchange to be known or guessed at by external parties. For example, two or more parties may exchange their confidential information while they encounter or merely pass close by each other.

4.1 Functional Components

Only the first four functional components discussed in section 2.2 may be required to construct an ad hoc m-commerce system because the network may be spontaneously and temporarily created when the need arises among mobile devices in close proximity to each other. However, there is a slight difference in the fourth component where an ad hoc wireless network like mobile ad hoc network (MANET) or Bluetooth is used as a medium to carry out the transactions as shown in Fig. 1.

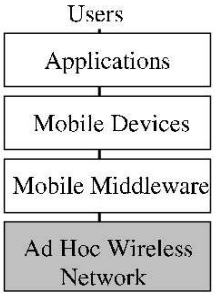

Fig.1. Four main functional components in an ad hoc m-commerce system.

Therefore, the design and development of m-commerce applications as well as mobile middleware must consider the unique characteristics of an ad hoc wireless network.

4.2 Main Entities

Since the transactions involve only mobile devices that are peers and have no guarantee of infrastructure support from a network service provider, there are only two essential entities involved in ad hoc m-commerce.

1) Customer or Trader
   The person who is mainly mobile and make use of the ad hoc wireless network to buy the digital contents, products or services offered by the seller or to trade contents, products or services for others.
2) Seller or Trader
   The person or entity that provides the digital contents, products or services directly to customers via ad hoc wireless networks for money or who trades contents, products or services for others.

Nevertheless, as different types of transactions would have different entity relationships, there are several possible essential entity relationships in the ad hoc m-commerce value chain. A relatively simple transaction might involve two mobile devices. For example, two people who are commuting in a train agree to exchange their e-magazines while they are within transmission range of each other. In a more complicated scenario where more than two mobile devices are involved in a transaction such as an auction, the entity relationship can be illustrated as below.

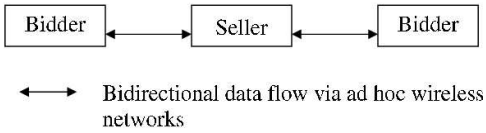

Fig.2. Transactions involving more than two mobile devices.

Fig. 3 and Fig. 4 illustrate two scenarios involving the formation of an ad hoc trading consortium among mobile users who are in the vicinity of each other and agree to band together for a specific purpose, for example to make a collective purchase (Fig. 3) or to engage in group trading (Fig. 4).

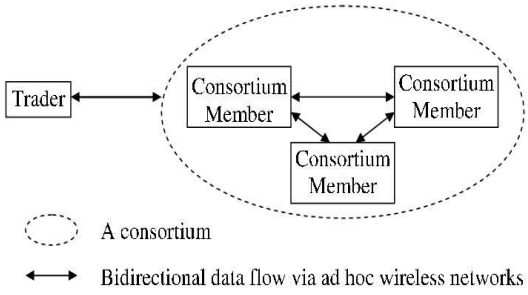

Fig.3. A group of individuals forming a consortium for trading.

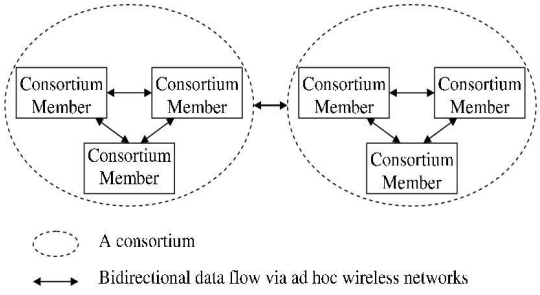

Fig. 4. Trading between two consortiums.

Fig. 5 shows a delegated trading scenario where an electronic I Owe U (IOU) is used to acknowledge debt between two parties trading via an ad hoc wireless network. It illustrates a scenario in a local community where Trader 1, who has a toaster, wants to trade it for an electric kettle. Trader 2, who is within Trader 1's communication range and owns an electric kettle, agrees to trade his electric kettle with Trader 1 but does not want a toaster. So, Trader 1 issues an electronic IOU signed by himself to Trader 2 as an acknowledgement of his debt to Trader 2. Trader 2 can later use that electronic IOU to trade for another item such as a pram that she wants with Trader 3, who wants a toaster. Trader 3 will then use the electronic IOU signed by both Trader 1 and Trader 2 to settle with Trader 1 for his toaster.

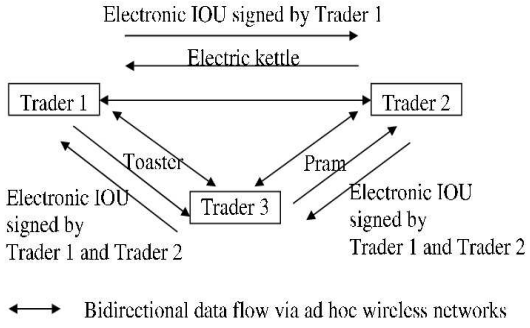

Fig. 5. A delegated trading scenario.

To represent various entity relationships in the ad hoc m-commerce value chain, a generic view of ad hoc m-commerce transactions is provided as Fig. 6.

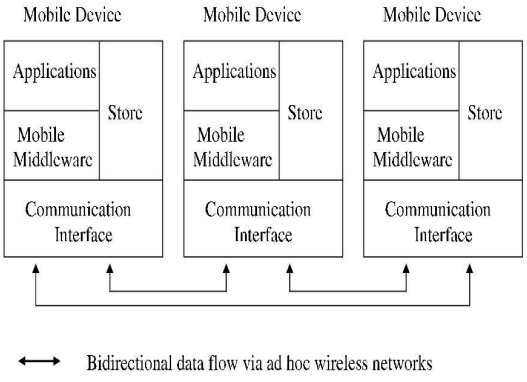

Fig. 6. A generic view of ad hoc m-commerce transactions. The ad hoc m-commerce store will hold certificates, attestations, offers, IOUs, deals and so on.

4.3 Types of Applications

There are several distinct types of m-commerce transactions that can be carried out over ad hoc wireless networks:

1. Swapping of digital resources
   Swapping of digital resources such as ebooks, videos, music files etc. For example, two people who meet by chance at an airport may agree to exchange an MP3 pop song for an amusing video clip.
2. Mobile Auction
   The process of buying or selling certain items could be realised by an auction among a local group of people. An auction process can be created anywhere as soon as a group of at least three persons with mobile devices and shared software agree to participate. This type of activity is amenable to short term participation by individuals and a rapid turnover in its membership as long as enough are usually present to create a critical mass of bidders. Multicasting among participants can disseminate bids and information about what is on offer.
3. Mobile Entertainment
   Interactive gaming and gambling among small groups of people is another kind of application suited to ad hoc networking. Applications running on mobile devices realise the game or gambling scenario, manage its communications and handle the turnover in participants. For example, people play blackjack over a mobile ad hoc wireless network using mobile devices like laptop computers, PDAs or computers in cars.
4. Transacting with Machines
   Transactions that use mobile devices that are preloaded with E-cash to make payment at a vending machine, point of sales (POS), parking tolls and so on via technologies such as Wi-Fi and Bluetooth.
5. Confidential Exchanges
   Two or more parties who meet at a certain place or pass in the vicinity of each other may agree to exchange their confidential information resources or services for a specific purpose.
6. Consortium Trading
   A group of individuals who are in the vicinity of each other and equipped with mobile devices could spontaneously and temporarily form a consortium for a specific purpose. For example, a group of football fans at a football ground might band together as a single buyer to purchase a discounted group ticket in order to get a cheaper ticket for each

of them to watch a match. Another example would be a group of football fans who form a consortium during a football match to engage in betting on the outcome with another group of football fans.

7. Electronic IOUs
   'I Owe U' or its abbreviation 'IOU' is an established means to acknowledge a small debt usually among friends or family members. This form of acknowledgement can be passed electronically via an ad hoc wireless network among trading parties. It can be signed to verify its authenticity and the identities of all handling parties.

4.4 Issues

Performing m-commerce transactions over ad hoc wireless networks introduces additional issues and challenges. In addition to the above issues, ad hoc wireless networks have specific issues that need to be considered. However, issues related to variant tariffs are not applicable to ad hoc wireless networks as no access fee is required to access the network. Other issues that need to be considered when performing ad hoc m-commerce:

1. Transaction management
   Due to its nature such as lack of infrastructure, having a dynamic network topology and using resource constrained devices, it is a challenge to implement efficient transaction processing and updates in purely ad hoc wireless networks. Most solutions used in infrastructure based m-commerce depend on a client/server model where data is primarily placed on servers located within the wired network and mobile devices act as clients accessing the services provided by the servers [17]. However, in ad hoc wireless networks, all devices are peers and normally have similar constraints on their resources. Thus, those devices act as both servers and clients. The mobility of mobile devices that provide services (servers) to other devices is an important issue as the services are prone to becoming unavailable due to network disconnections. Also, the atomicity of a transaction can be difficult to enforce as network disconnections can cause a particular service in a transaction sequence to fail and thus the transaction would be considered incomplete and be aborted [17].
2. Service Discovery and Delivery
   A service discovery and delivery protocol enables devices to advertise their services to other devices as well as to discover services offered by other devices in the network. However, due to the unique characteristics and complexities of an ad hoc wireless network, existing service discovery and delivery protocols do not seem to suit the needs of an ad hoc wireless network, making them unsuitable for m-commerce oriented scenarios. Service advertisements and deliveries may need to be disseminated by a mix of a store and forward strategy as well as local multicasting to cope with intermittent online connectivity.
3. Trust
   Trust is essential in any online transactions as it helps the participating parties to feel confident enough to engage in such transactions by mitigating uncertainty and risks involved in the transactions, such as uncertainty about trading partners' behaviour in fulfilling the transaction agreements [18]. However, as ad hoc m-commerce cannot rely on a network service provider to provide security services such as certification authority (CA) that can help to establish trust among nodes in the network, nodes have to rely on their peers in the network to provide trust evidence in order to evaluate other nodes' trustworthiness. Yet, the nature of an ad hoc wireless network such as lack of infrastructure services, having a dynamic network topology, using resources constrained devices and so on, makes trust establishment in this network difficult to achieve.

4.5 Security Requirements

To create a sufficiently secure and trusted environment for a transaction to take place as well as to give confidence to trading parties to engage in a transaction, the following security services are essential.

1. Confidentiality
   Confidentiality ensures that transaction information sent across the network is unreadable by unauthorized third parties such as eavesdroppers or peers acting only as communication relays.
2. Authentication
   Authentication enables trading parties involved in m-commerce transactions to confirm the identity of each other

before any transactions are made among them. This service provides assurance that an unauthorized third party is not masquerading as a legitimate party.

3. Integrity
   Integrity guarantees that a message being transferred is not illicitly altered or destroyed during the transmission without this being detectable at the receiving end of an m-commerce system.
4. Non-repudiation
   Non-repudiation ensures that if an entity sends a message, it cannot get away with denying having sent the message. In m-commerce transactions, neither sender nor receiver should credibly be able to repudiate offers or bargains struck between them. The sender should not be able credibly to deny having sent the transaction message and the receiver should be able to prove that the transaction message can only have been sent by the specified sender and thus able to prove that a transaction has taken place between them.

In addition to the above, as m-commerce transactions involve the risk of misbehaviour among the trading parties, they need support in gauging the level of trustworthiness of other trading parties. Hence, attestation is another important security service for ad hoc m-commerce.

5. Attestation
   Attestation enables ad hoc m-commerce peers to vouch for the identity, trading history or transaction reputation of other peers. It helps mitigate risks in transacting with previously unknown parties.

5 CONCLUSION

An ad hoc wireless network can be an alternative to operator-driven GPRS/UMTS networks that provide networking support for m-commerce transactions, particularly in supporting spontaneous and low value transactions in ad hoc settings among unacquainted parties. It seems most suited to fully online resource swapping that does not require complex and lengthy processes and also to online launched trading in local communities where parties can easily meet to transfer goods and payment as agreed.

We believe that the elements of an ad hoc m-commerce reference model presented in this paper will be useful in designing and developing a wide range of ad hoc m-commerce applications and also valuable as a basis for future research in various aspects of ad hoc m-commerce. Our future work will be focusing on the issue of trust in ad hoc m-commerce. We will be developing a trust model that will enhance the security of an ad hoc wireless network as well as mitigate risks and uncertainties involved in the transactions, to make an ad hoc wireless network a sufficiently commercial secure and trusted medium for transactions to be able to take place. Simulation processes and experiments will be conducted to evaluate the effectiveness of the trust model.

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